Productivity of the STAR Group

The scientific research mission and unique role of the STAR group at BNL:

To perform forefront research and advance the state of knowledge in relativistic heavy ion physics

To provide experience and scientific leadership in order to create a fertile intellectual environment leading to important experimental advances by thesis students and other STAR researchers

To develop new analysis methods and detector technologies for future exploration at RHIC and beyond, leading to a deeper level of scientific exploration

This research is directly relevant to the DOE NP strategic plan/NSAC LRP/NP long term performance measure: *Recreate brief, tiny samples of hot, dense nuclear matter to search for the quark gluon plasma and characterize its properties.*

Concerning the first two goals of the scientific research mission and unique role of the STAR group at BNL:

- To perform forefront research and advance the state of knowledge in relativistic heavy ion physics
- To provide experience and scientific leadership in order to create a fertile intellectual environment leading to important experimental advances by thesis students and other STAR researchers

The researchers and their roles:

STAR Council
50 institutions,
13 countries
Chair; H. Crawford
BNL Rep: J. Lauret

STAR Spokesperson
Xu
Deputy Spokespeople
Barranikova, Dunlop, Surrow

Talks Committee
Huang (Chair), Dong,
Margetis, Mioduszewski,
Peitzmann, Sumbera,
Van Buren

STAR Upgrades

Leader	Videbaek
IST	Surrow
HFT	Ritter/Videbaek
FGT	Hassell
TOF	Eppley / Xu/ Ruan
DAQ1000	Ljubicic/Landgraf
FMS	Bland
pp2pp	Guryn
EPD	Sorensen
SSD	LeVine/Thomas
TOF+TPC PID:	Fachini, Fisyak, Dong
HF Trig	Ullrich, Liu, Lima
MTD R&D	Xu, Ruan
HLT R&D	Ljubicic, Lauret, Tang

STAR Physics Working Groups
Physics Analysis Coordinator: Mohanty

Bulk Correlations:	Raniwala, Sorensen
Heavy Flavor:	Dong, Calderon
Jet-like Correlations:	Putschke, Ray, Wang
Light Flavor Spectra:	Ruan, Takahashi
Spin:	Sowinski, Sichtermann
UPC:	Gorbunov, Guryn

BES Focus Group: Sorensen, Keane, Odyniec

STAR Group Leader: Hallman

Administrative: Mogavero, Feliciano

STAR Operations

Detector Support Group

Leader:	Christie
DAQ:	Ljubicic, Landgraf
TPC:	Thomas, Lebedev
Trigger:	Crawford
HLT:	Tang, Ljubicic
Magnet:	C-AD
Slow Crls:	Cherney
BEMC:	Tsai
EEMC:	Sowinski/Jacobs
FTPC/Laser:	Lebedev
ZDC:	Xu, Tang
BBC/FMS:	Bland
TOF :	Ruan, Xu, Eppley, Llope
PMD:	Viyogi/Chattopadhyay

Technical Support Group

Vacant	Head ME
D'agostino	Head EE
Soja	MT
Scheblein	Designer
Kuchewski	ET
Asselta	ET
Scheetz	EE, DAQ1000
Hammond	ET
Dias	ET

Software & Computing

Lauret	Leader
Didenko	Production
Vacant	GEANT
Perevotichikov	Root/IO
Fysiak	Reco Leader
Faine	Graphics
Arkhipkin	Online/Database
Betts, Ahrenstein	Real Time Support
Van Buren	Calibration Ldr
Vacant	PDSF/ Embedding
Witt/Thomas	TPC calibration
Levente	Grid Development

BNL Scientific Staff;
BNL Professional Staff;
Non-BNL Staff

* Matt Lamont is a post doc in the group working on EIC

The researchers and their roles:

STAR Upgrades:	
Leader	Videbaek
IST	Surrow
HFT	Ritter / Videbaek
FGT	Hassell
TOF	Eppley / Xu / Ruan
DAQ1000	Ljubicic / Landgraf
FMS	Bland
pp2pp	Guryn
BES Instrumentation	Sorensen
SSD	LeVine / Thomas
TOF+TPC PID	Fachini-Laue, Fisyak, Dong
HF Trig	Ullrich, Liu, Lima
MTD R&D Xu, Ruan	

An essential contribution in addition to basic research, rather unique because of the group's location at BNL, is development of new techniques and detector instrumentation to extend scientific reach. This contribution has been central to 4 of the 5 STAR upgrades developed thus far (FMS, TOF, DAQ1000, HFT)

Positions of responsibility and scientific leadership recently held by members of the BNL STAR Group

- STAR Deputy Spokesperson (Dunlop 2008 – present)
- STAR Light Flavor Spectra Physics WG Co-convener (Ruan 2008 – present)
- STAR Bulk Correlations Physics WG Co-Convener (Sorensen 2008 – present)
- STAR Ultra-peripheral Collisions Physics WG Co-Convenor (Guryn 2008 – present)
- STAR Beam Energy Scan Focus Group Co-Convener (Sorensen 2007 – present)
- STAR Upgrades Leader (Videbaek 2009 – present)
- STAR Operations Leader (Christie 2000 – present)
- STAR Software and Computing Leader (Lauret 2002 – present)
- STAR DAQ (Ljubicic 2000 – present)
- STAR DAQ1000 Upgrade Leader (Ljubicic 2007 – present)
- STAR Embedding Coordinator (Fachini-Laue 2008 – present)
- STAR Calibrations Leader (Van Buren 2003 – present)
- SSD Electronic Readout Upgrade Leadership (Levine 2008 – present)
- TOF Testing and Commissioning Leadership (Ruan, Xu 2008 – present)
- TPC Operations Support (member of 2 person team) (Lebedev 2008 – present)
- RHIC II Steering Committee (Ullrich, Xu 2008 – present)
- E-RHIC Working Group (Ullrich (leader), Dunlop, Xu)
- DNP Education Committee (Hallman, 2008 – present)
- DNP Summer School Organizing Committee (Ullrich, 2008)
- Member, NSAC (Ullrich, 2007- 2008)

Quality of leadership both nationally and internationally

Recent papers on which group members were principal authors

Published FY 2008 - 2009

- "Centrality Dependence of charged hadron and strange hadron elliptic flow from $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions", Phys. Rev. C77, 054901 (2008).

- "Spin alignment measurements of the K*(892) and φ(1020) vector mesons in heavy ion collisions at $\sqrt{s_{NN}}$ = 200 GeV", Phys. Rev C77, 061902 (2008).

- "Hadronic resonance production in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV measured at the BNL Relativistic Heavy Ion Collider", Phys. Rev. C78, 044906 (2008)

- "System size independence of directed flow measured at the BNl Relativistic Heavy Ion Collider", Phys. Rev. Lett. 101 (2008) 252301

- "Systematic Measurements of Identified Particle Spectra in p+p, d+Au, and Au+Au collisions from STAR, Phys. Rev. C79 034909 (2009)

Submitted FY 2008 - 2009

- "J/ψ production at high tranvserse momentum in p+p and Cu+Cu collisions at $\sqrt{s_{NN}}$ = 200 GeV", arXiv: 0806.0513

- "Charge independent (CI) and charge dependent (CD) correlations as a function of centrality formed from Δφ and Δη charged pair correlations in minimum bias Au+Au collisions at 200 GeV", arXiv: 0806.0513

- "Charmed hadron production at lowe transverse momentum in Au+Au collisions at RHIC", arXiv: 0805.0364

In 2008-2009, 9 Ph.D. students, 1 M.Sc., 3 high school students were mentored by BNL STAR Group members

Demonstrated competency and future promise of research personnel:

From FY2008 – FY2009, group members played a leading role in 8 scientific publications and gave 57 talks at major international conference including presentations at:

Quark Matter	2008 (Fachini, Ullrich, Hallman, Debbe); 2009 (Dunlop, Fachini,Tang, Ullrich, Videbaek);
Gordon Conf	2009 (Ullrich);
DIS	2008 (Lamont, Ullrich); 2009 (Lamont, J.H. Lee)
WWND	2008 (Ruan); 2009 (Lamont);
Hot Quarks	2008 (Lamont)
Hard & EM Probes	2008 (Ullrich (2))
CHEP	2009 (Hadju, Lauret, Zerola, Jakl)
ACAT	2008 (Faine, Zerola)

One member of the group (Hallman) is a 2006 APS Fellow

One member (Sorensen) is an APS George E. Valley Prize winner

Two members are Presidential Early Career Scientist Award Winners (Xu-2005; Sorensen-2009)

Two members (Ruan, Sorensen) have been Gertrude & Maurice Goldhaber Distinguished Post Doctoral Fellows

One member is an Adjunct Professor at Yale University (Ullrich)

Quality of leadership both nationally and internationally:

Group members play an important role in organizing international scientific meetings:

Quark Matter	(08, Hallman; 09 Ullrich)
Int Symp. Multi-Particle Dynamics	(07, Hallman)
Strange Quark Matter	(08 & 09 Hallman, Ullrich)
Conf. Intersect of Particle and Nucl Phys	(06, Dunlop)
ICHEP	(06, Hallman)
Hard Probes	(08, Ullrich)
Hot Quarks	(06, 08 Ullrich, Organizer & Co-Founder of series)
Particles and Nuclei in Collision	(05, Ullrich; 08, Hallman)

and in detailed scientific discussions as members of God Parent Committees or Principal Authors.

A "God Parent Committee" is a group of experienced, knowledgeable Collaboration members who receive a paper manuscript from the Principal Authors, and review it for scientific correctness and literary soundness prior to final review by the Collaboration before submission

A Principal Author is one of a small number of scientists who has performed an original scientific analysis or technical development and written it up for submission to a refereed journal for publication

Quality of leadership both nationally and internationally:

Group members play an important role in organizing international scientific meetings:

Quark Matter	(08, Hallman; 09 Ullrich)
Int Symp. Multi-Particle Dynamics	(07, Hallman)
Strange Quark Matter	(08 & 09 Hallman, Ullrich)
Conf. Intersect of Particle and Nucl Phys	(06, Dunlop)
ICHEP	(06, Hallman)
Hard Probes	(08, Ullrich)
Hot Quarks	(06, 08 Ullrich, Organizer & Co-Founder of series)
Particles and Nuclei in Collision	(05, Ullrich; 08, Hallman)

and in detailed scientific discussions as members of God Parent Committees or Principal Authors. For paper published or presented in 2008-2009 group members:

Chaired a God Parent Committee (GPC) 7 times:	Xu (2), Fachini, Lee, Guryn, Tang, Videbaek
Were Principal Authors 29 times on 15 out of 40 papers (= 38%)	Fachini-Laue, Ruan, Ullrich, Longacre ,Lindebaum, Sorensen, Tang Xu, Zhang, Grube, Chung
Were members of a GPC other than being a Principal Author 40 times:	Christie, Fachini-Laue,Lamont, Debbe, Lee Longacre, Sorensen, Dunlop, Videbaek Tang, Ullrich, Van Buren, Ruan, Guryn, Xu

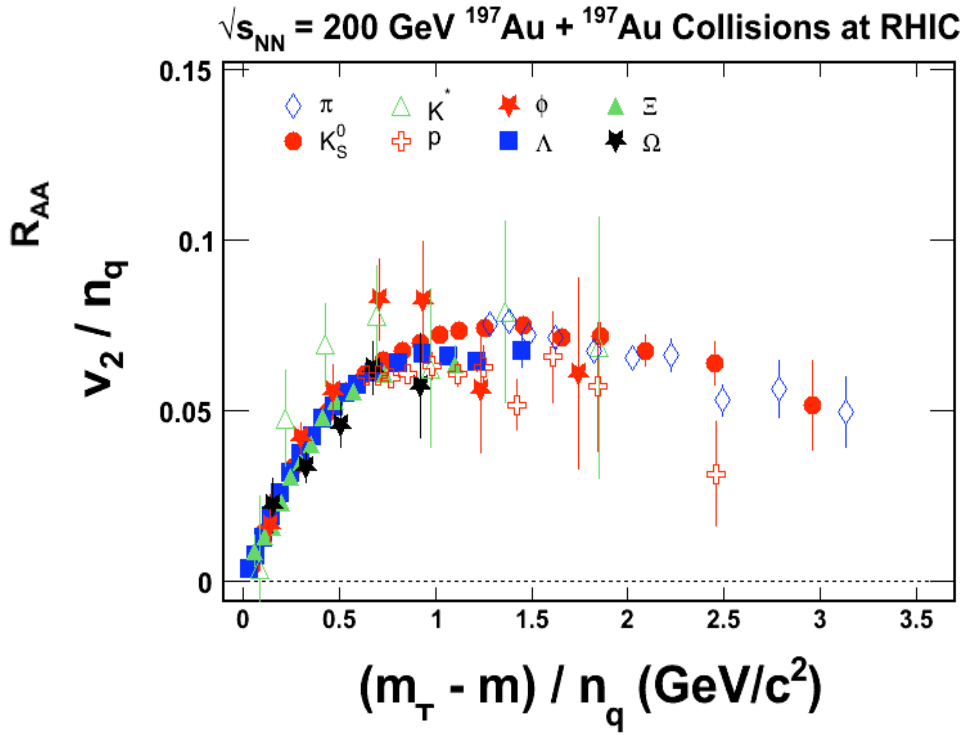
The context for this research: a major discovery—a new state of matter
The goal: discovery of the properties of the matter uniquely produced at RHIC

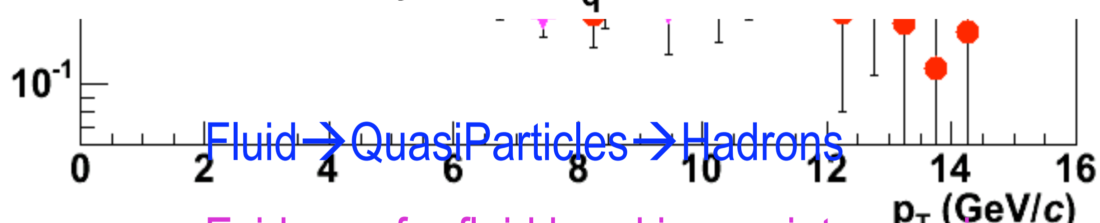
The hottest, densest matter yet examined in the laboratory

It is highly opaque to colored probes– quarks and gluons – but not to photons

It flows as a relativistic quantum liquid with minimal shear viscosity

It produces copious mesons and baryons with yield ratios and flow properties that suggest their formatio[n] via coalescence of valence quarks from a hot thermal bath.





Fluid→QuasiParticles→Hadrons

Evidence for fluid breaking up into quasi-particles with quantum numbers of quarks before hadrons

For reasonable T (~ 2T_c) and τ (~ 1 fm/c) data suggest η/s << 0.3

The compelling scientific questions being attacked by the STAR group:

- What are the fundamental properties of strongly interacting QCD matter ?
  - Study of elliptic flow as a window on the equation of state and initial conditions which generate the (almost) Perfect Liquid discovered at RHIC (DM2)
  - Study of identified high p_T spectra and heavy quark energy loss to understand the dependence of transport coefficients on color charge and quark flavor (DM1 & 5)
  - Study of quarkonia suppression to determine the effects of screening of color charge in the matter (DM1 & DM5)
- What are the phases of strongly interacting matter, and what roles do they play in the cosmos?
  - Search for a critical point in the QCD phase diagram (DM6)
- What determines the key features of QCD, and what is their relation to the nature of gravity and spacetime?
  - Study of J/Ψ spectra to test theory which posits a universal lower bound on viscosity per unit entropy (η/s) for strongly coupled systems (DM8)

The compelling scientific questions being attacked by the STAR group:

- What are the fundamental properties of strongly interacting QCD matter ?
  - Study of elliptic flow as a window on the equation of state and initial conditions which generate the (almost) Perfect Liquid discovered at RHIC (DM2)
  - Study of identified high p_T spectra and heavy quark energy loss to understand the dependence of transport coefficients on color charge and quark flavor (DM1 & 5)

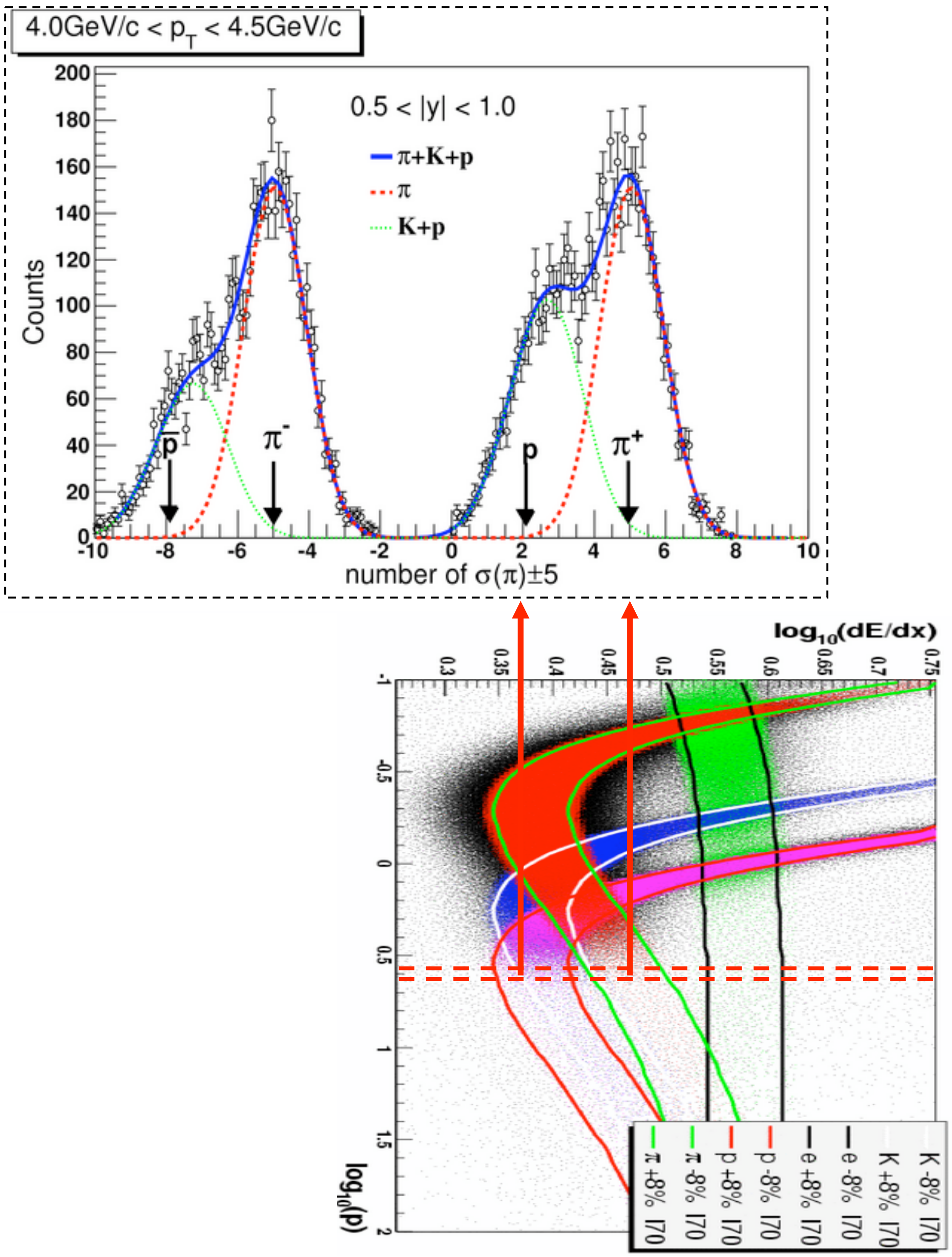
Important advances as a result of this research:

- Yield and spectra of heavy quark hadrons cause paradigm shifts in the theoretical explanation of parton energy loss; high p_T J/Ψ spectra test models of quarkonia production
- Flow studies indicate flow build up at a partonic stage; flow fluctuations consistent with initial state Colored Glass Condensate
- Identified, high p_T particle yields and spectra challenge pQCD based models of parton energy loss

t

A few selected highlights

A major contribution: developing hadron Identification at high p_T



A key advance from members of the BNL group:

- Initiate and develop PID from TPC dE/dx at the relativistic rise
- Calibrate dE/dx to be much better than proton and pion separation
- Continuous identification of pion and proton from 0.2 → 15 GeV/c (TPC +TOF)

Publications as Principal Authors:

L. Ruan, P. Fachini, Z. Xu, P. Sorenson,

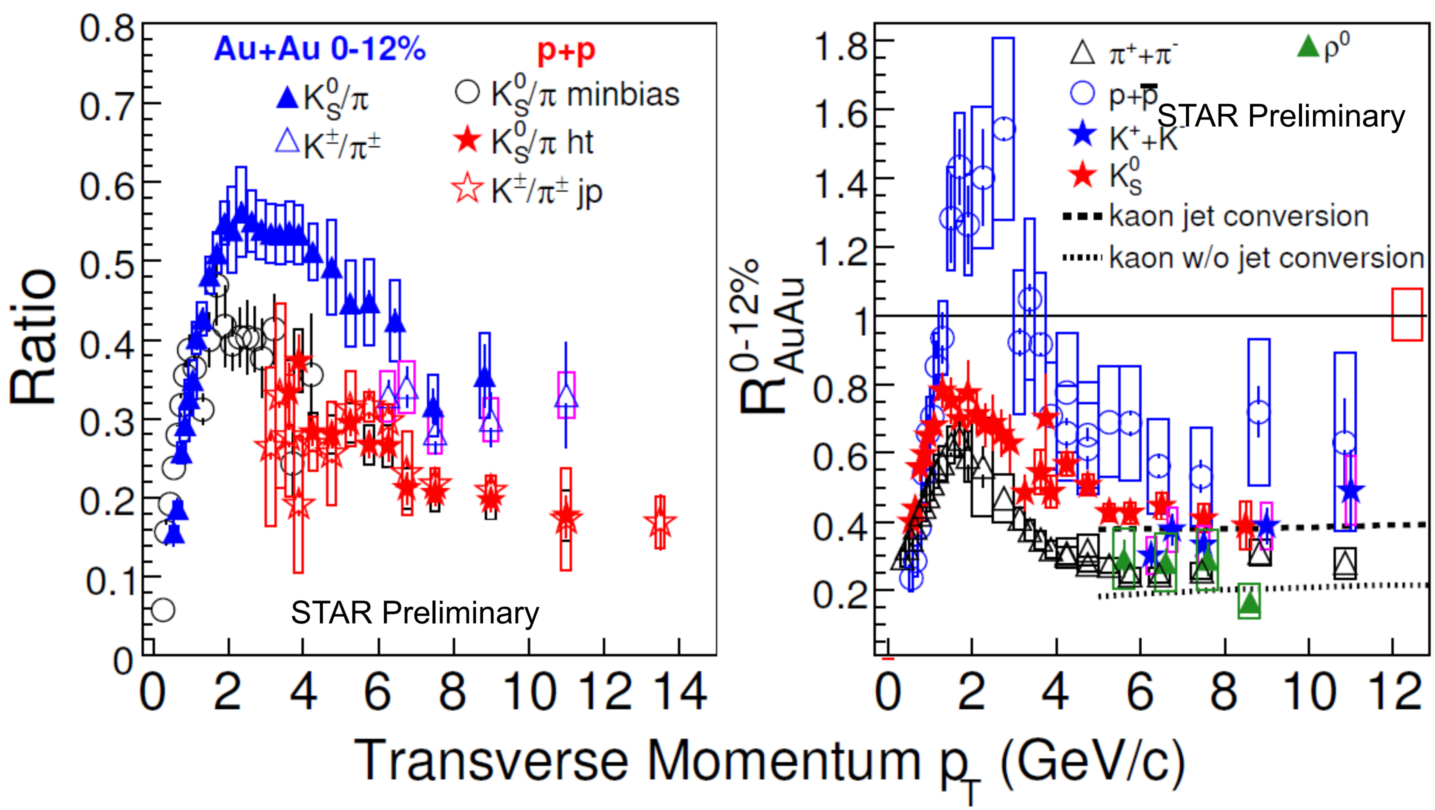
Visiting students:

Haidong Liu, Pawan Natrakanti, Yichun Xu

Nucl.Instrum.Meth. A558 (2006) 419-429

Int.J.Mod.Phys. A20 (2005) 3783-3785

Identified hadron spectra to "stress-test" models of pQCD energy loss and study changes in the final jet hadron chemistry in Au+Au vs p+p



Using high p_T identified particle to probe the medium:
The final jet hadron chemistry was observed to change:

- K/π (Au+Au) > K/π (p+p)
- R_{AA}(p+pbar) ≥ R_{AA}(K) > R_{AA} (π) ~ R_{AA}(ρ)
- Consistent with jet conversion mechanisms and/or modified enhanced parton splitting in a hot, dense medium

Principal Authors: Yichun Xu (USTC/BNL), Lijuan Ruan, Zhangbu Xu, P. Fachini, A. Timmins, G. Van Buren, L. Barnby, J. Dunlop

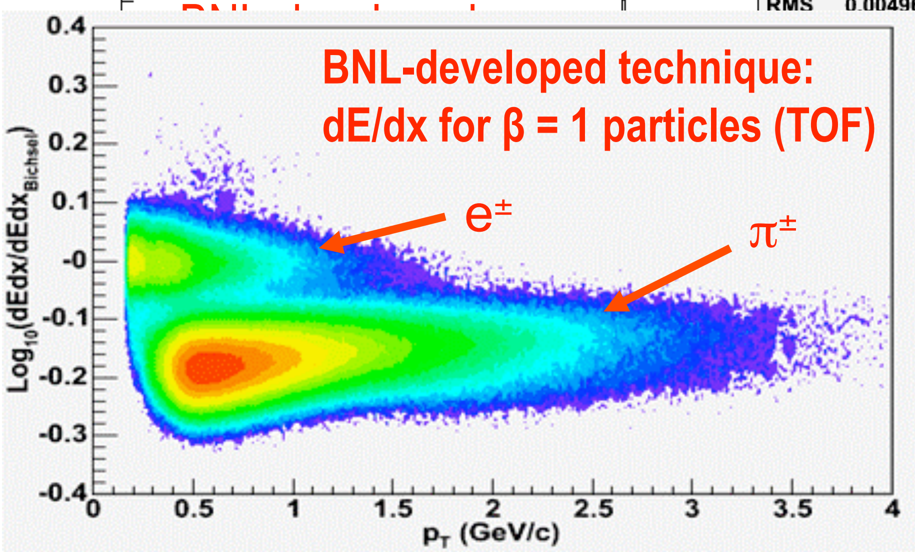
A central issue: yields and spectra of heavy-quark hadrons

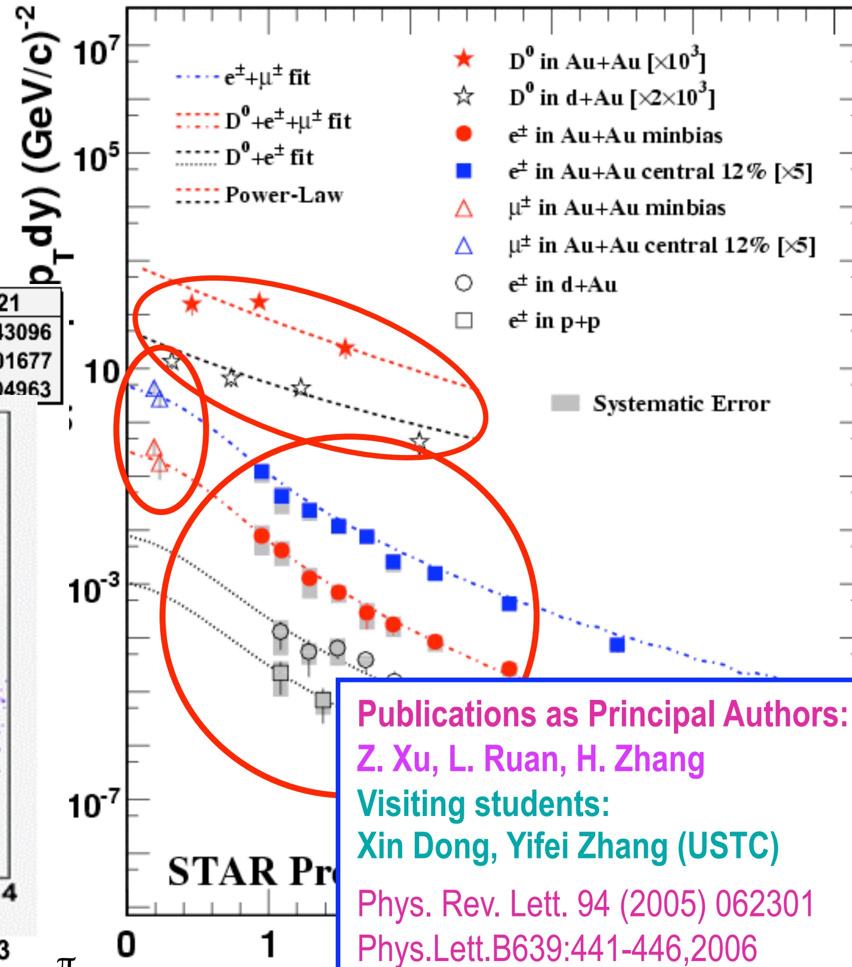
- The BNL STAR Group has pioneered the measurement of D mesons in multiple decay channels using both standard techniques and novel approaches that it has developed

"Brute-force" combinatoric subtraction

Low p_T muons from semi-leptonic decays

Electrons from semi-leptonic decays



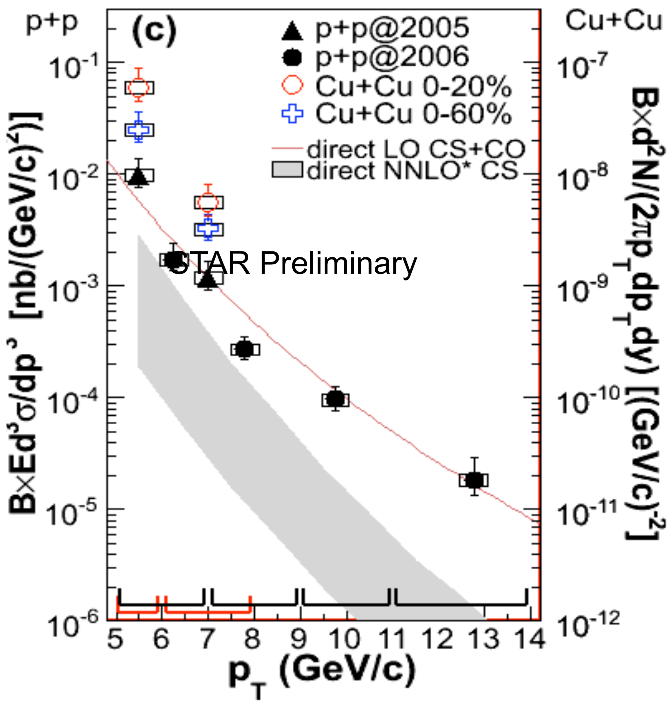


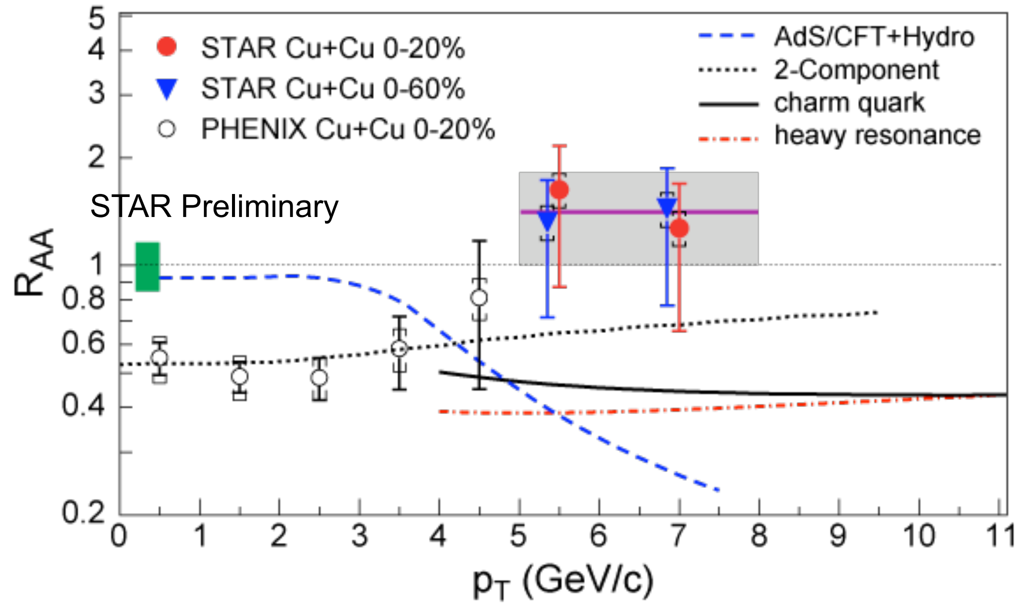
Publications as Principal Authors:
Z. Xu, L. Ruan, H. Zhang
Visiting students:
Xin Dong, Yifei Zhang (USTC)

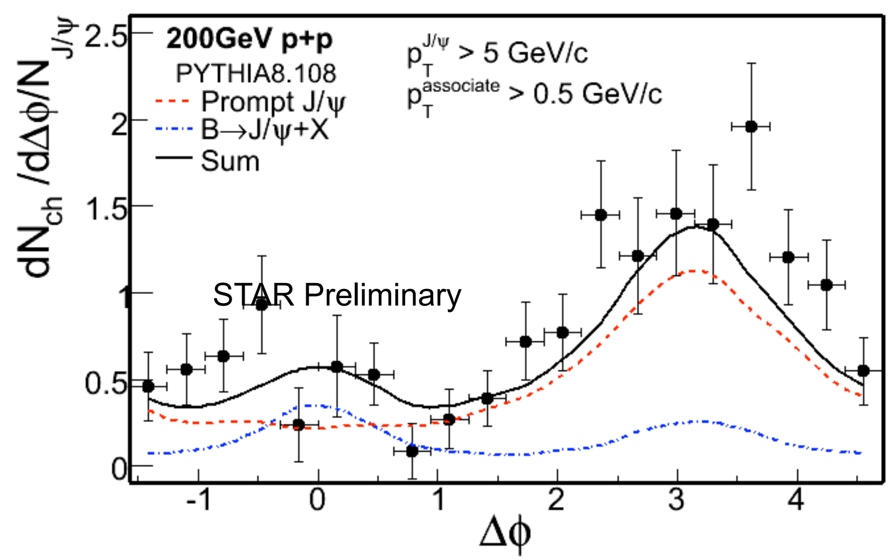
Phys. Rev. Lett. 94 (2005) 062301
Phys.Lett.B639:441-446,2006
Nucl.Instrum.Meth.A558:419-429,2006

$\sigma_{c\bar{c}}$ ~ scales with the number of binary collisions

High p_T J/ψ production mechanisms and medium properties: R_{AA}, spectra & correlations







Using nuclear modification factors and spectra to understand J/ψ production mechanisms and medium properties:

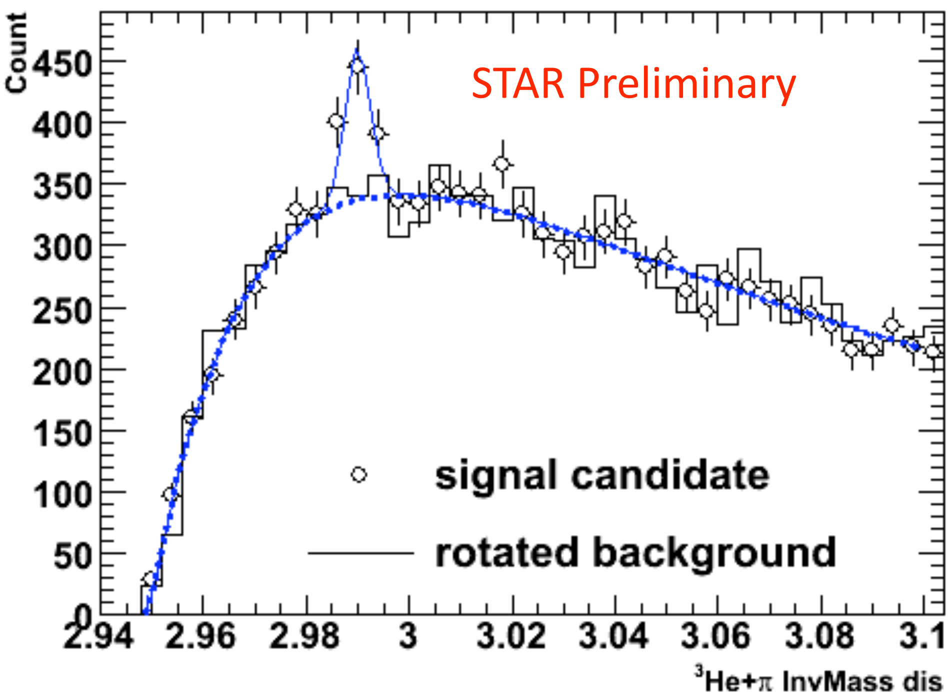
- Spectrum shape at high p_T shows deviation from color singlet model predictions.
- R_{AA}: Contrast to AdS/CFT+ Hydro prediction
- Correlations shows low B contribution (13 ± 5)%

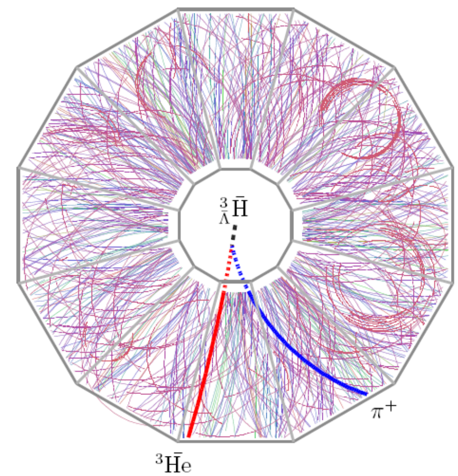
arXiv: 0904.0439

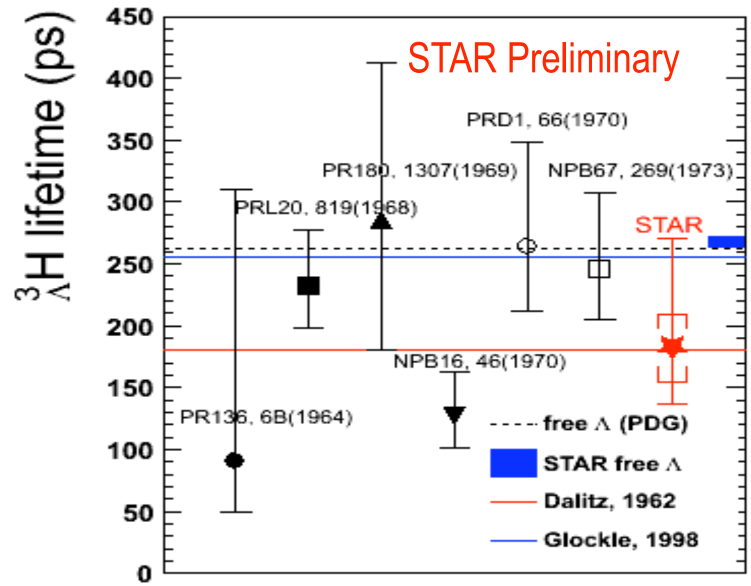
Principal Authors: Zebo Tang (USTC/BNL), Lijuan Ruan, Zhangbu Xu, Thomas Ullich, Yifei Zhang, Mauro R. Cosentino

Discovery of the anti-hyper-triton

Combine hyper-triton and anti-hyper-triton signal:
225 ± 35 counts







This provides a > 6 σ signal for a discovery claim

Principal Authors:
Jinhui Chen, Declan Keane (Kent),
Zhangbu Xu, Zebo Tang, Hao Qiu (BNL)
Hank Crawford (LBL)

[1] R. H. Dalitz, *Nuclear Interactions of the Hyperons* (Oxford Uni. Press, London, 1965).

[2] R.H. Dalitz and G. Rajasekharan, Phys. Letts. 1, 58 (1962).

[3] H. Kamada, W. Glockle at al., Phys. Rev. C 57, 1595(1998).

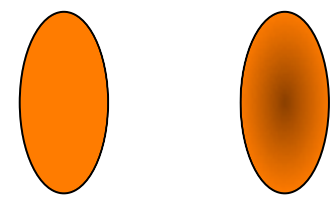
Deeper insight by group members (Sorensen/Tang) into a key RHIC observable:

The observation of large elliptic flow is the basis for several major findings in the first phase of RHIC. (For example, that the matter appears to flow as a “perfect liquid”.)

…But how much of the flow comes from the initial state in the entrance channel nuclei vs dynamical evolution after the collision

One way to tell, ..fluctuations in the amount of elliptic flow…

Is the initial state a sataurated gluon density or Glauber distribution?



CGC Glauber

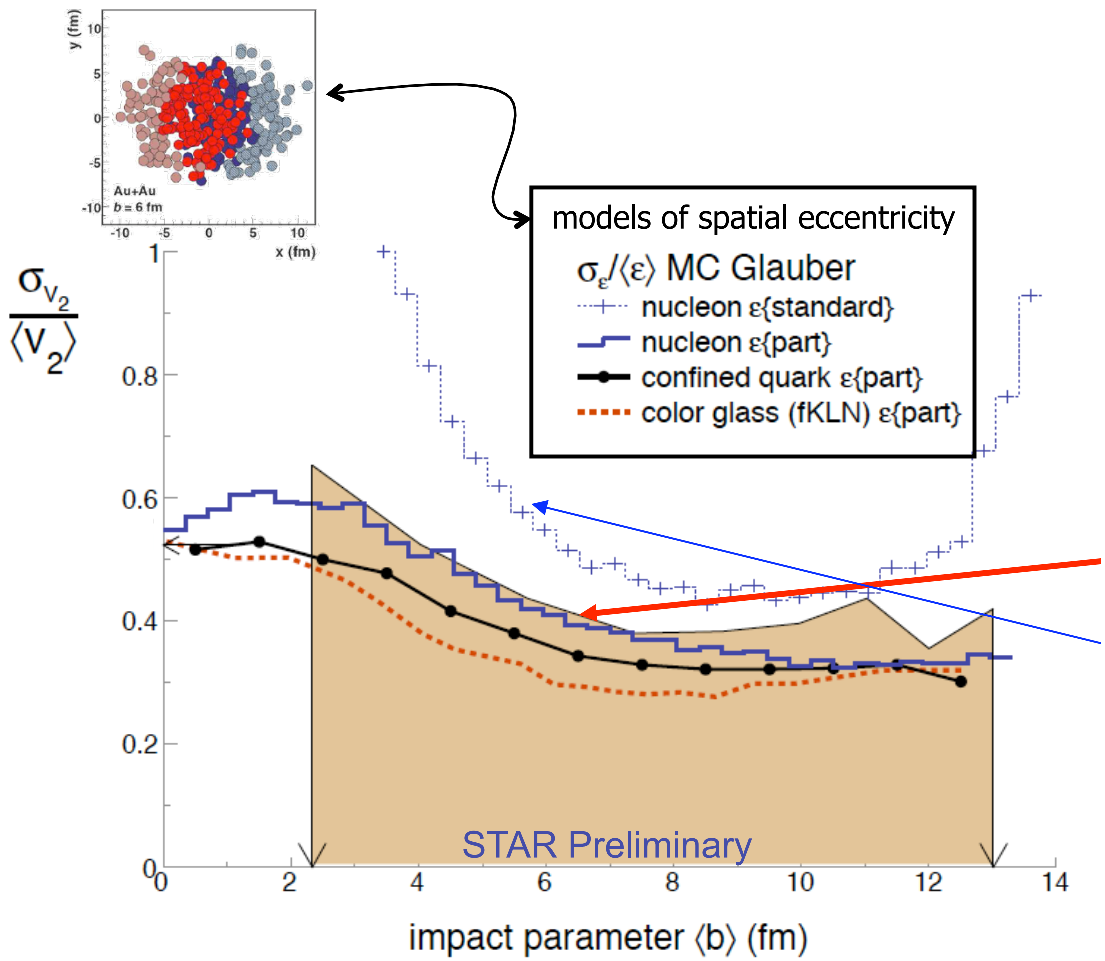
CGC: Treats the nucleus as a saturated gluon field

The assumption about the initial conditions effects initial eccentricity of the overlap zone

Deeper insight by group members (Sorensen/Tang) into a key RHIC observable:

Comparison with models of geometry fluctuations:

→ working towards a better understanding of effects from the initial state



confined quark MC:
- treats confined constituent quarks as the participants
- decreases eccentricity fluctuations

color glass MC:
- includes effects of saturation
- increases the mean eccentricity

An active area of research:

comparison to hydro (NexSPheRio): *Hama et.al. arXiv: 0711.4544*

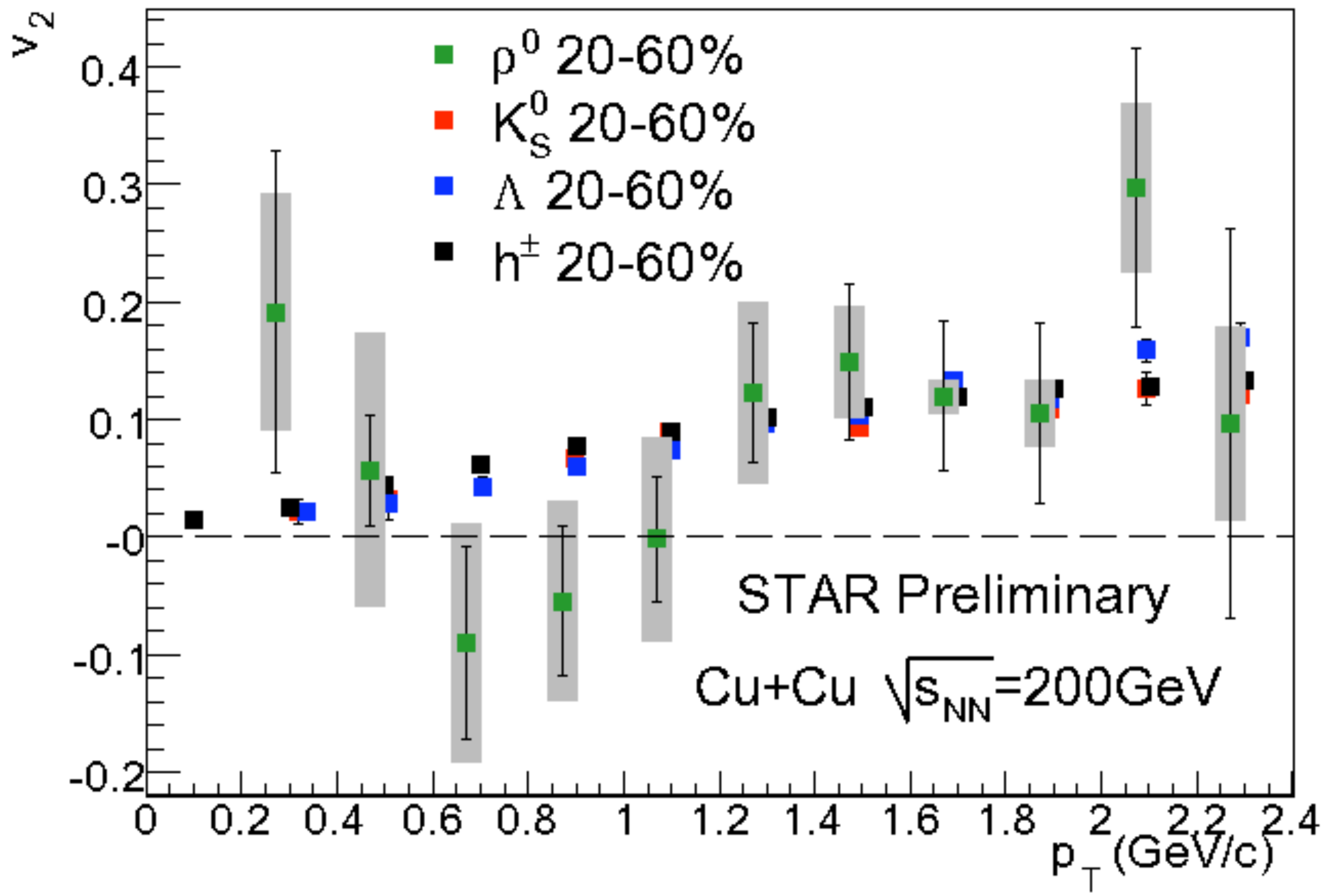
eccentricity fluctuations from CGC: *Drescher, Nara. Phys.Rev.C76:041903,2007*

extraction of Knudsen number: *Vogel, Torrieri, Bleicher. nucl-th/0703031*

fluctuating initial conditions: *Broniowski, Bozek, Rybczynski. Phys.Rev.C76:054905,2007*

first disagreement with $\varepsilon_{standard}$ and use of quark MC: *Miller, Snellings. nucl-ex/0312008*

First Measurement of ρ^0 Elliptic Flow



- ρ^0 v_2 tests constituent quark scaling and contribution of regeneration
- Significant ρ^0 v_2 measured $\Rightarrow$ $p_T > 1.2$ GeV/c $\Rightarrow$ $v_2 \sim 13 \pm 4\%$.

Research Plan 2008-2012

- Main direction: characterizing the properties of the new form of matter discovered at RHIC

- Key Topics
  - Heavy flavor and quarkonia production to test models of parton energy loss and screening in the plasma
    - High-p_T J/ψ, Bottomonium ϒ, D mesons & correlations
  - Flow and flow fluctuations to test collectivity of heavy quark hadrons and assess the degree of thermalization in the partonic stage
    - Heavy flavor flow
  - Identified particle spectra & correlations to test models of parton energy loss and their dependence on quark flavor
    - Extended p_T range with ToF
  - Low mass dileptons to study resonances in-medium
  - Search for a possible critical point in the QCD phase diagram

A lead role by the STAR group at BNL in preparing for a RHIC Beam Energy Scan

Group members playing a leading role in the motivation, planning and preparation:

Paul Sorensen (BES & PWG Co-convenor)
Zhangbu Xu (Hypertriton and trigger)
Lijuan Ruan (ToF)
Bill Christie (trigger and detector setup)

Alexei Lebedev (FTPC support)
Les Bland (BBC suppport)
Aihong Tang (Fast Tracking/Trigger)
Flemming Videbaek (detector readiness)

Test runs carried out and analyzed by BNL/STAR group:

analysis of flow — v_1 and v_2
development of appropriate triggers
analysis of expected event rates

simulations carried out for K/π fluctuations
simulations carried out for v_1 and v_2

Leadership of the community in meetings and studies culminating in a document detailing a run-plan, physics priorities, and a list of required events:

3 workshops held at BNL in 2008 and 2009

CPOD International Workshop: June 8^{th}-12^{th}

Local organizing committee:
Karsch, Ludlam, Satogata, Sorensen, Stephens

The result: a whitepaper on the motivation and means for a RHIC BES

Experimental Study of the QCD Phase Diagram and Search for the Critical Point: Selected Arguments for the Run-10 Beam Energy Scan at RHIC

The STAR Collaboration (B. I. Abelev et al.)

Introduction & Summary

We present an overview of the main ideas that have emerged from discussions within STAR for the Beam Energy Scan (BES). The formulation of this concise and abridged document is facilitated by the existence of a much longer and more comprehensive companion document entitled *Experimental Exploration of the QCD Phase Diagram: Search for the Critical Point* [1]. The compelling arguments and motivations for the physics of our proposed Beam Energy Scan program, which have a particular role in guiding the run plan (see p. 13) as set out in our discussion of Tables 1 and 2, are (not in order of priority):

Beam Energy	Event Rate	8-hr Days/ 1M Events	Events proposed	8-hr days proposed
5	0.8	45	100 k	5
7.7	3	11	5 M	56
11.5	10	3.7	5M	19
17.3	33	1.1	15M	16
27	92	0.4	33M	12
39	190	0.2	24M	5

Table 1: The proposed run duration at each energy is determined by the number of Minimum Bias events needed to perform the detailed measurements discussed in the previous sections; see Table 2.

	Collision Energies (GeV)	5	7.7	11.5	17.3	27	39
Section	Observables	Millions of Events Needed					
A1	n_q scaling π/K/p/Λ $(m_T-m_0)/n$<2GeV	8.5	6	5	5	4.5	4.5
A1	ϕ/Ω up to p_T/n_q=2 GeV/c		56	25	18	13	12
A2	R_{CP} up to p_T ~4.5 GeV/c (at 17.3) 5.5 (at 27) & 6 GeV/c (at 39)				15	33	24
A3	untriggered ridge correlations		27	13	8	6	6
A4	parity violation		5	5	5	5	5
B1	v_2 (up to ~1.5 GeV/c)	0.3	0.2	0.1	0.1	0.1	0.1
B1	v_1	0.5	0.5	0.5	0.5	0.5	0.5
B2	Azimuthally sensitive HBT	4	4	3.5	3.5	3	3
B3	PID fluctuations (K/π)	1	1	1	1	1	1
B3	net-proton kurtosis	5	5	5	5	5	5
B3	differential corr & fluct vs. centrality	5	5	5	5	5	5
B3	integrated p_T fluct (T fluct)						

A. Turn-off of QGP Signatures and Other New Phenomena

(A-1) Constituent-quark-number scaling

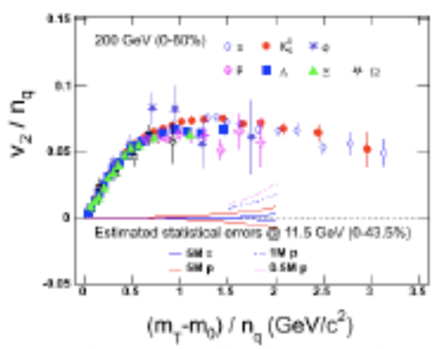
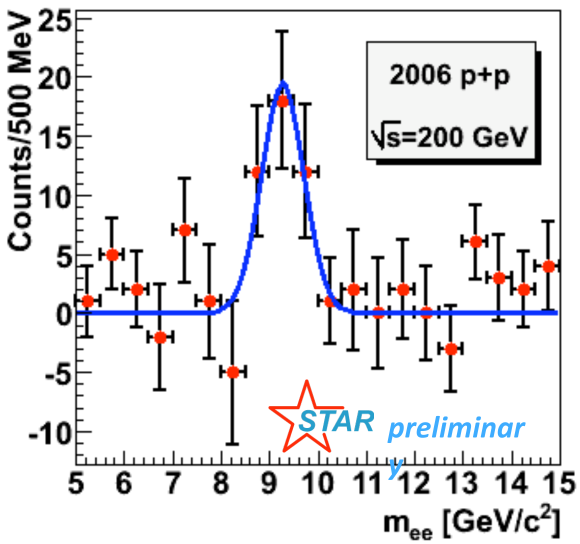


Fig. 2: Elliptic flow per constituent quark versus transverse mass per constituent quark for Au + Au collisions at 200 GeV at RHIC. See text for explanation of solid and dashed curves near v_2 = 0.

When elliptic flow v_2 is plotted versus transverse kinetic energy $(m_T - m_0)$, v_2 for all identified particles below $m_T - m_0$ = 0.9 GeV/c^2 falls on a universal curve. Above that, meson and baryon v_2 deviates, with baryon v_2 rising above meson v_2 and saturating at a value approximately 50% larger than for mesons; however, upon dividing each axis by the number of constituent quarks (n_q = 2 for mesons and 3 for baryons), the meson and baryon curves merge very impressively into a single curve over a wide range of $m_T - m_0$, as seen in Fig. 2. This well-known scaling behavior is one of the most striking pieces of evidence for the existence of partonic degrees of freedom during the Au + Au collision process at 200 GeV. It is very hard to explain this pattern in a scenario where only hadronic matter exists throughout the interaction, whereas the hypothesis of coalescence of hadrons from deconfined quarks offers a ready explanation.

A future test of color screeing in the plasma: Bottomonium (Υ)

First Υ measurement

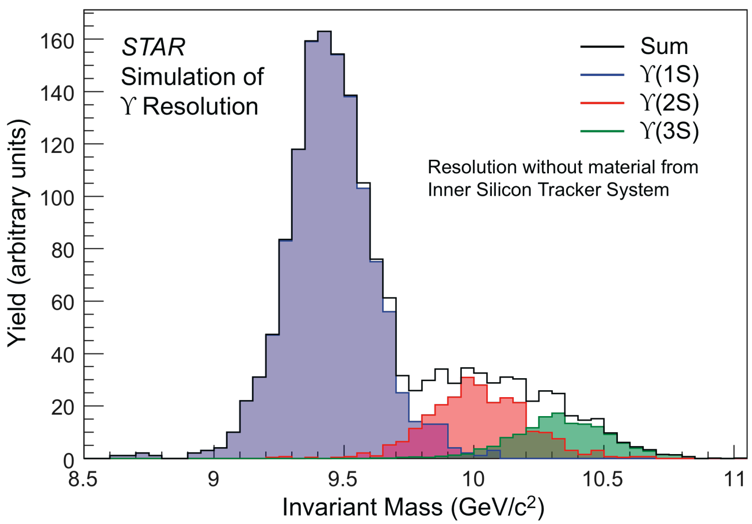


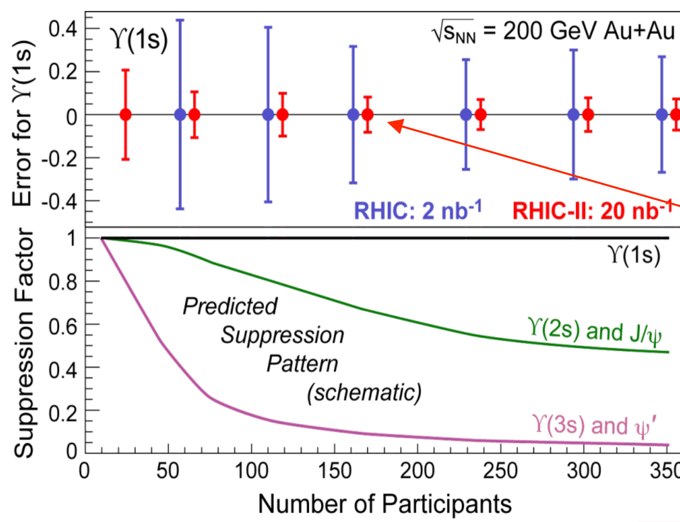
The Υ, Υ', Υ'' should behave differently than the J/Ψ

- Υ(1S) no melting at RHIC ⇒ standard candle
- Υ(2S) likely to melt at RHIC (analog J/ψ)
- Υ(3S) melts at RHIC (analog ψ')

Features

- co-mover absorption negligible
- recombination negligible at RHIC
- STAR has an efficient trigger and large acceptance
- BNL STAR Group has significant expertise in trigger and electron PID





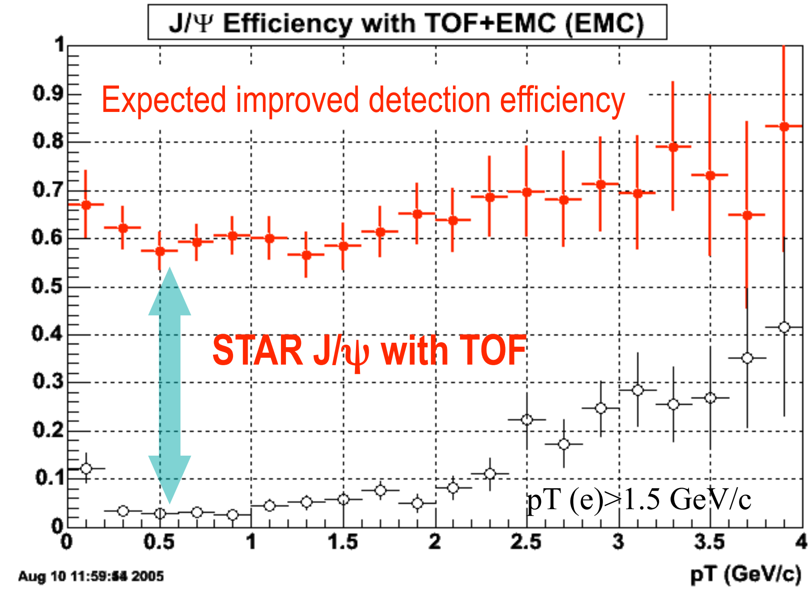
Υ→e^+e^-:
T. Ullrich et al

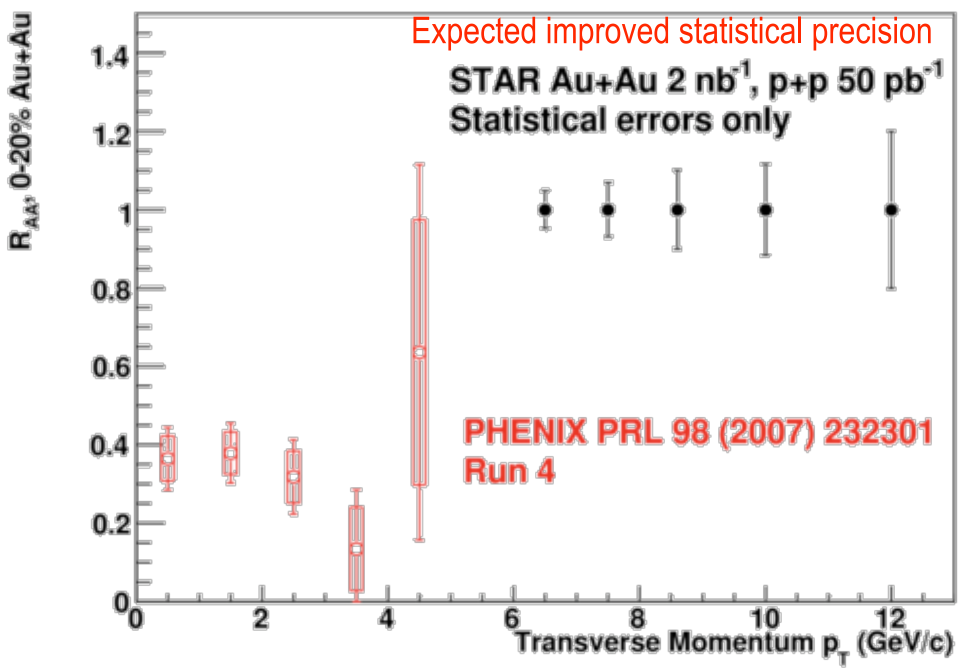
Statistical precision Expected with RHIC II luminosity

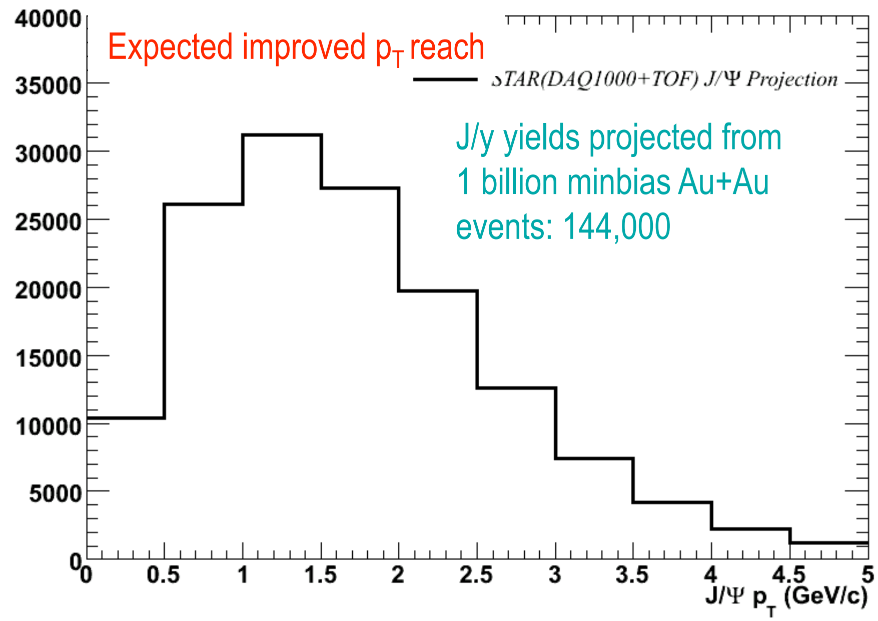
25

Future STAR Group studies of J/ψ to test models of quarkonia production

- Group will utilize Electron PID with TOF+TPC+EMC covering large p_T range
- It will further develop a J/Ψ trigger at high-p_T
- Scientific motivation: study thermalization & Color DOF
  - Test Color Screening
  - Coalescence of charm quarks
  - J/Ψ Elliptic flow v_2





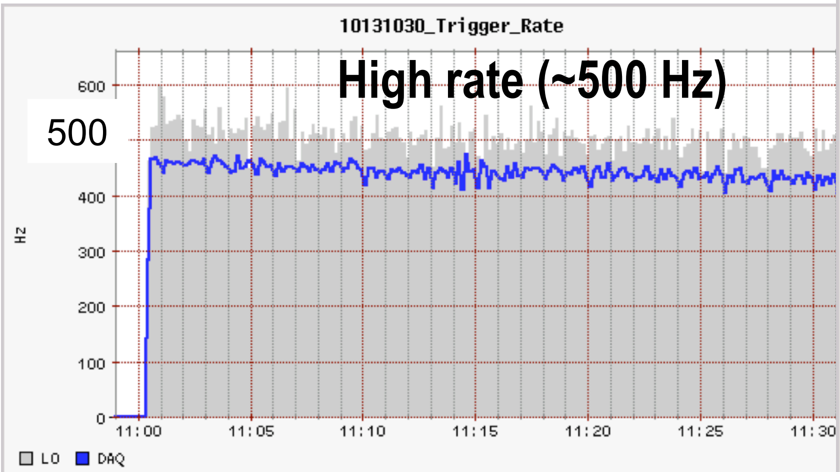


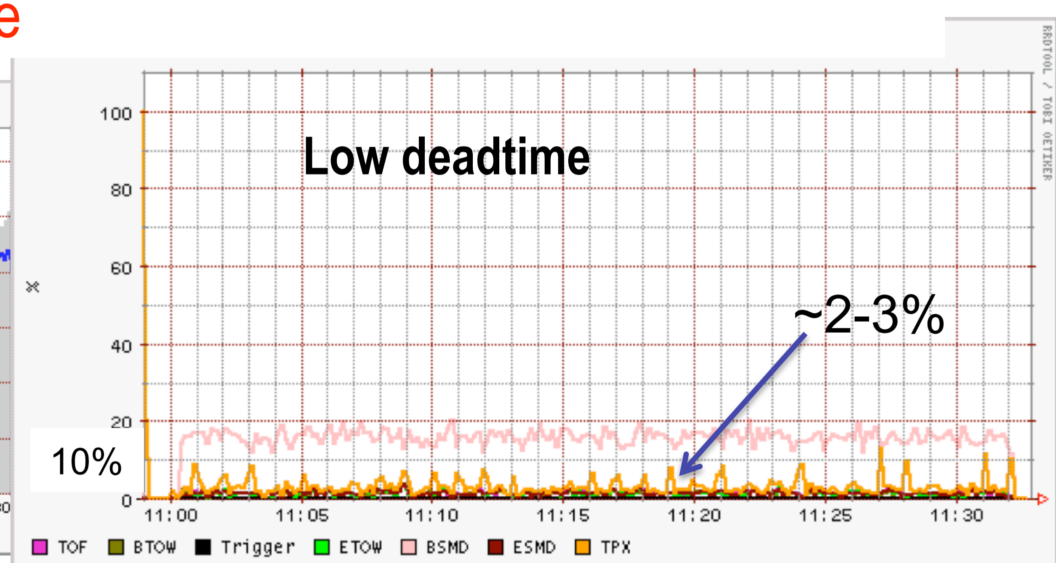
L. Ruan, Z. Xu, J. Dunlop, T. Ullrich
Visiting student:
Zebo Tang

The third goal of the scientific research mission and unique role of the STAR group at BNL:

to develop new analysis methods and detector technologies for future exploration at RHIC and beyond, leading to a deeper level of scientific exploration

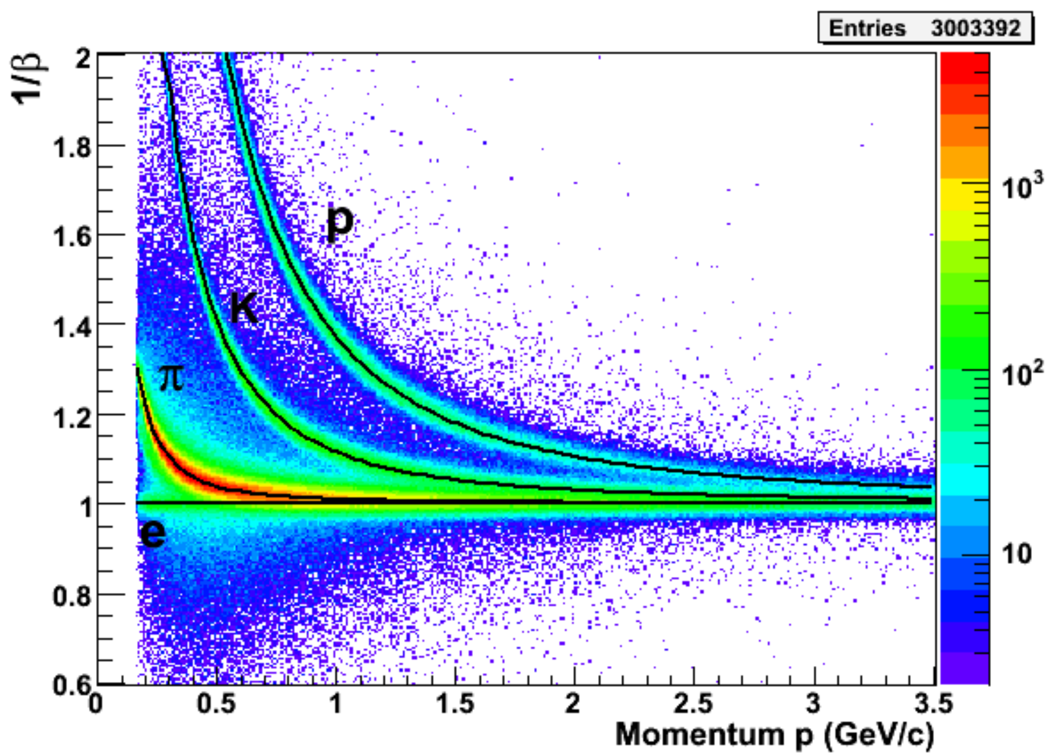
DAQ1000 — A BNL STAR Group responsibility to reduce dead time for rare probes and provide more bandwidth for physics — finished on budget, ahead of schedule





- FY09 was the first run with the full TPC equipped with new electronics ("DAQ1000")
- Run was a complete success: on average STAR ran at ~500 Hz (compared to 50 Hz in previous years) with 2-3% dead time
- Minor problems: 4 (out of 144) Readout Boards failed due to unknown reasons – investigating
- Single Event Upsets (SEU) at a rate of 1 in 30 minutes (over 5000 Front End Electronics cards), especially in pp500
- Plan to modify the firmware with SEU auto-sense and auto-recovery for the FY10 runs.

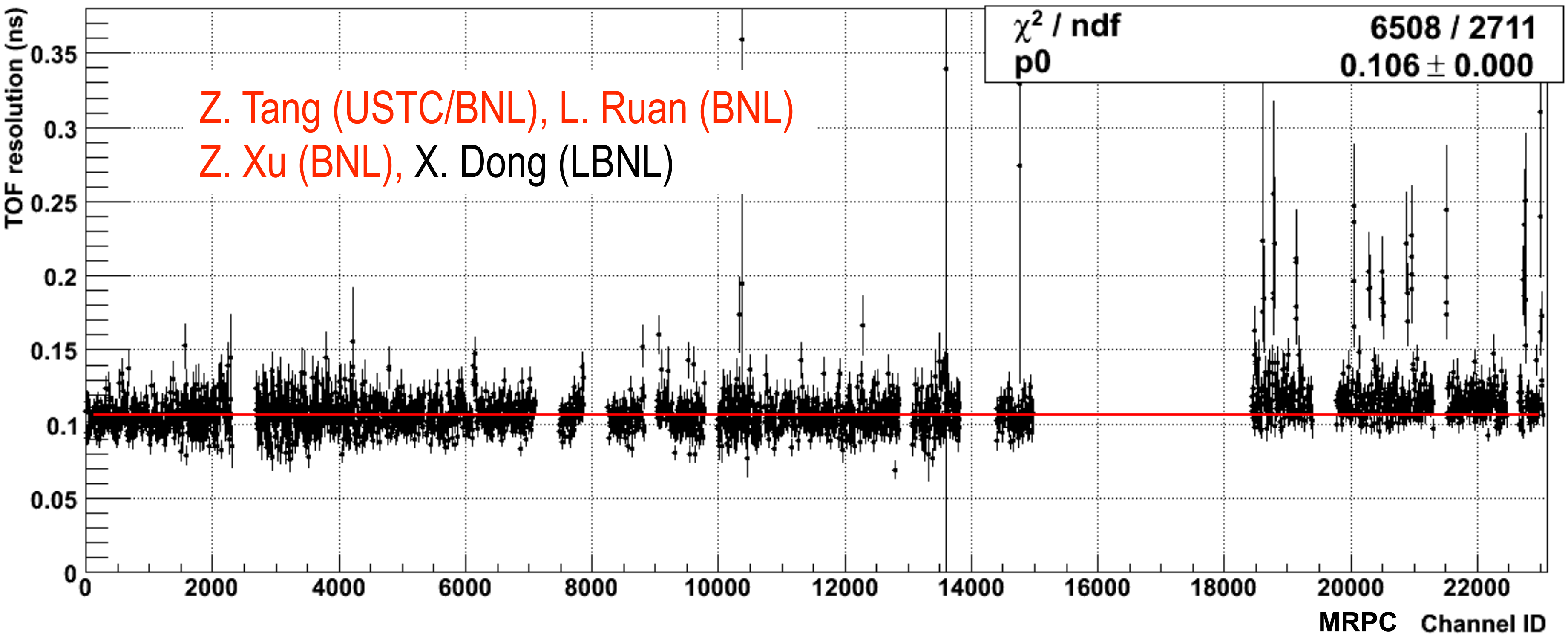
A leading role by the BNL STAR Group in commissioning newly installed TOF counters



New TOF barrel took data stably in run9 with 72% of the full acceptance (86 trays in Run 9)

Timing resolution: Start Time ~85 ps; Overall Resolution ~115 ps → Stop Time ~78 ps, which will be improved after final calibration of TPC

A leading role by the BNL STAR Group in commissioning newly installed TOF counters



Z. Tang (USTC/BNL), L. Ruan (BNL)
Z. Xu (BNL), X. Dong (LBNL)

New TOF barrel took data stably in run9 with 72% of the full acceptance (86 trays in Run 9)

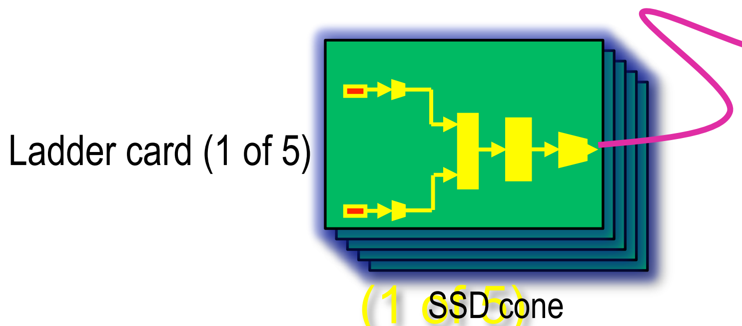
Timing resolution: Start Time ~85 ps; Overall Resolution ~115 ps → Stop Time ~78 ps, which will be improved after final calibration of TPC

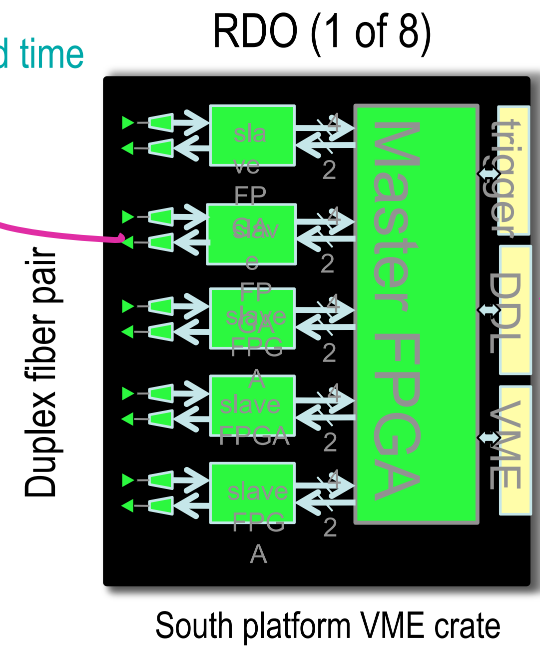
A BNL STAR Group responsibility: lead role on upgrade of the Silicon Strip Detector (SSD) readout for future Heavy Flavor Tracker (HFT)

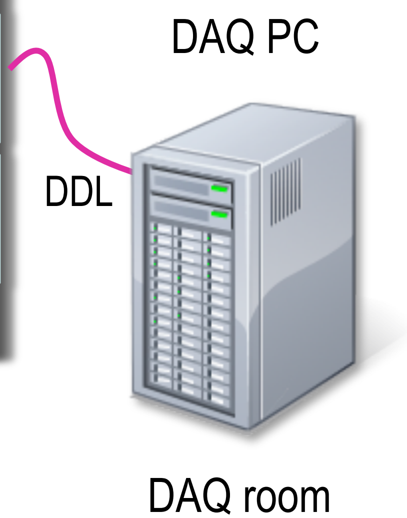
M.J. LeVine, C. Renard, R.A. Scheetz,
S. Bouvier, H.S. Matis, J.H. Thomas

Motivation

- SSD will be the outer layer of the new HFT inner tracker
- Original performance requirement was 100 Hz
- TPC DAQ upgrade now allows 1 kHz with low dead time
- SSD readout must be compatible with new DAQ







Strategy

- Replace single ADC with 16 ADCs
  - digitize 16 modules in parallel
- Increase sampling rate to 5 MHz

} 2.5 ms -> 153 µs

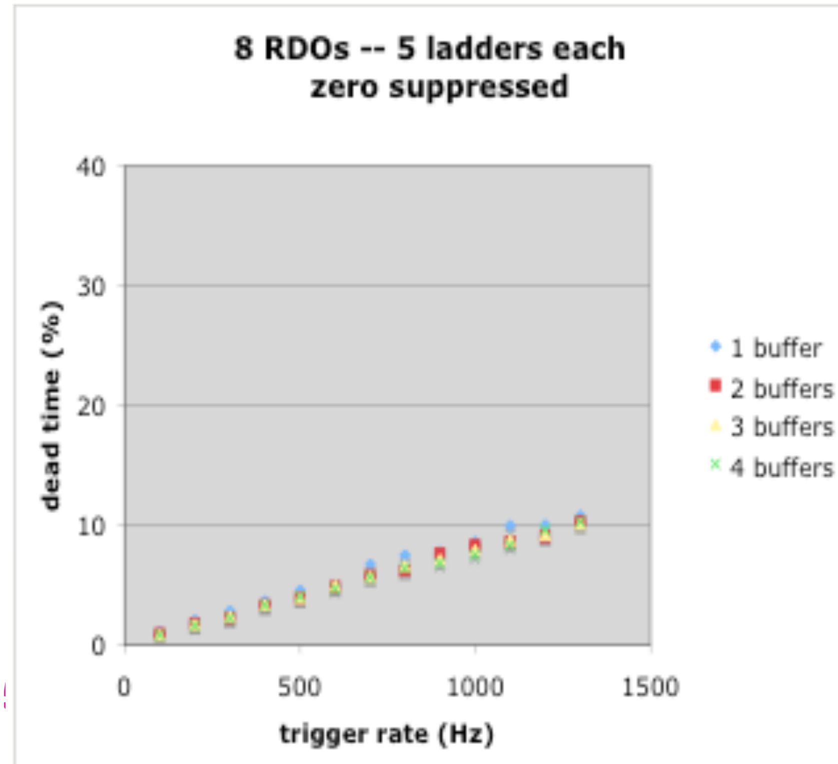
- All ladders processed concurrently
- Increase link speed to DAQ PC to 120 Mbyte/s per 5 ladders: 1850 µs -> 730 µs
- Multiple (derandomizing) buffers

A BNL STAR Group responsibility: lead role on upgrade of the Silicon Strip Detector (SSD) readout for future Heavy Flavor Tracker (HFT)

M.J. LeVine, C. Renard, R.A. Scheetz,
S. Bouvier, H.S. Matis, J.H. Thomas

Short Summary:

BNL STAR Group members playing a lead role in this upgrade which is essential for the success of the HFT



BNL STAR Group proposal to enhance di-muon study of quarkonia at RHIC II

Quarkonium dissociation temperatures – Digal, Karsch, Satz

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T_d/T_c	2.10	1.16	1.12	> 4.0	1.76	1.60	1.19	1.17

The temperature at which various resonances dissociate is a matter of debate, But there is no debate that different binding will lead to different dissociation patterns which can be used to study color screening in the medium

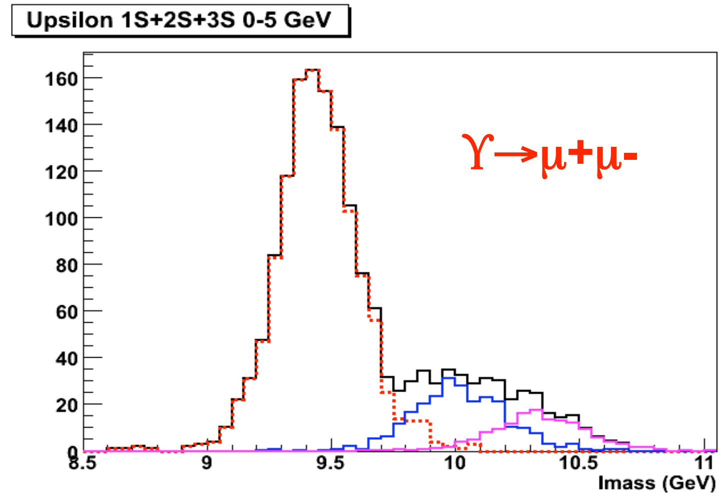
BNL STAR Group proposal to enhance di-muon study of quarkonia at RHIC II

Quarkonium dissociation temperatures – Digal, Karsch, Satz

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T_d/T_c	2.10	1.16	1.12	> 4.0	1.76	1.60	1.19	1.17

A large area of muon telescope detector (MTD) at mid-rapidity, **allows for the detection of:**

- **di-muon pairs** from QGP thermal radiation, quarkonia, light vector mesons, possible correlations of quarks and gluons as resonances in QGP, and Drell-Yan production
- **single muons** from their semi- leptonic decays of heavy flavor hadrons
- **advantages over electrons:** no γ conversion, much less Dalitz decay contribution, less affected by radiative losses in the detector materials



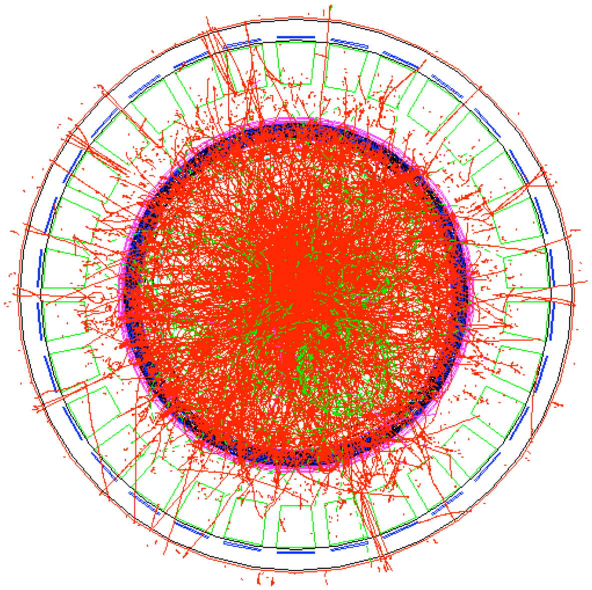
The Υ, Υ', Υ'' should behave differently than the J/Ψ

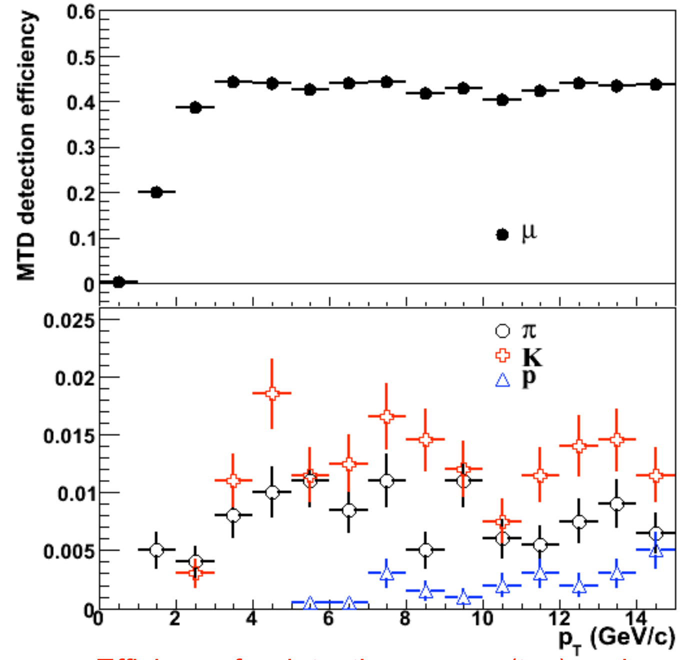
- Υ(1S) no melting at RHIC $\Rightarrow$ standard candle
- Υ(2S) likely to melt at RHIC (analog J/ψ)
- Υ(3S) melts at RHIC (analog ψ')

Features

- co-mover absorption small
- recombination negligible at RHIC

Muon Tracking Detector: Basic Concept

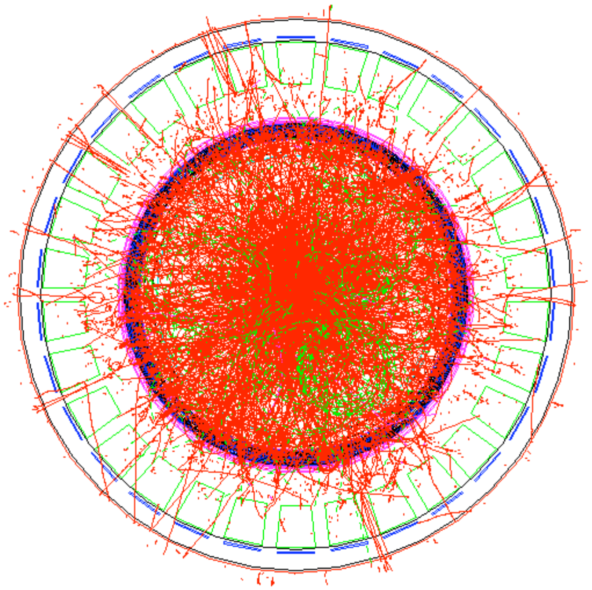


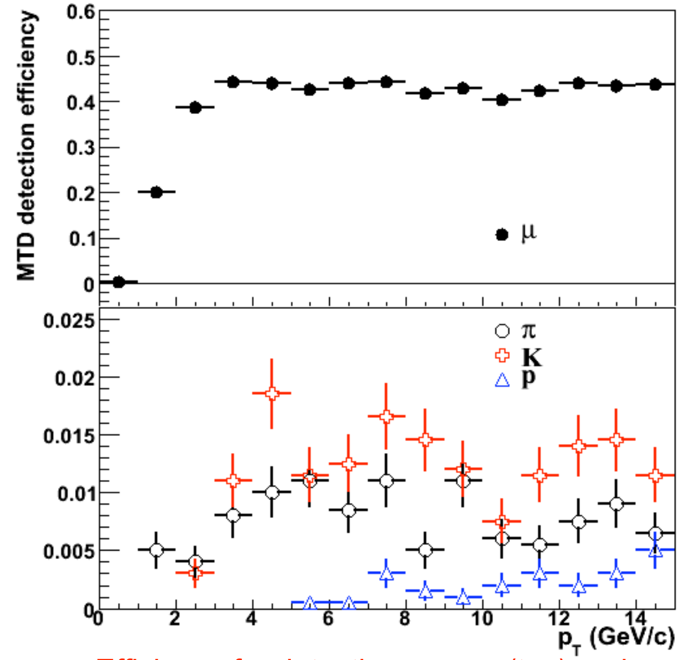


Efficiency for detecting muons (top) and hadrons (bottom) after the STAR return steel

Basic strategy: detect charged particles which do not range out in the return steel of the STAR magnet, whose tracks in the STAR TPC match within 400 ps with the hit position in a multi-gap resistive plate chamber having long longitudinal strips read out on both ends

Muon Tracking Detector: Basic Concept





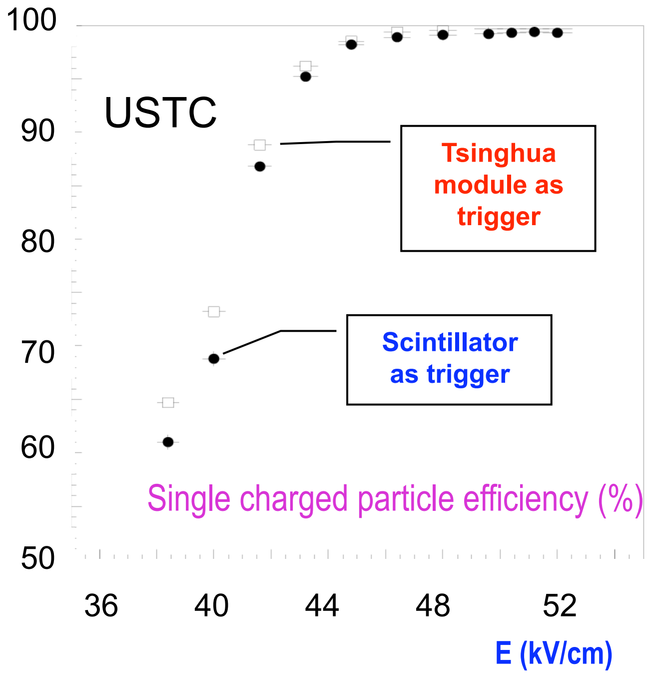
Efficiency for detecting muons (top) and hadrons (bottom) after the STAR return steel

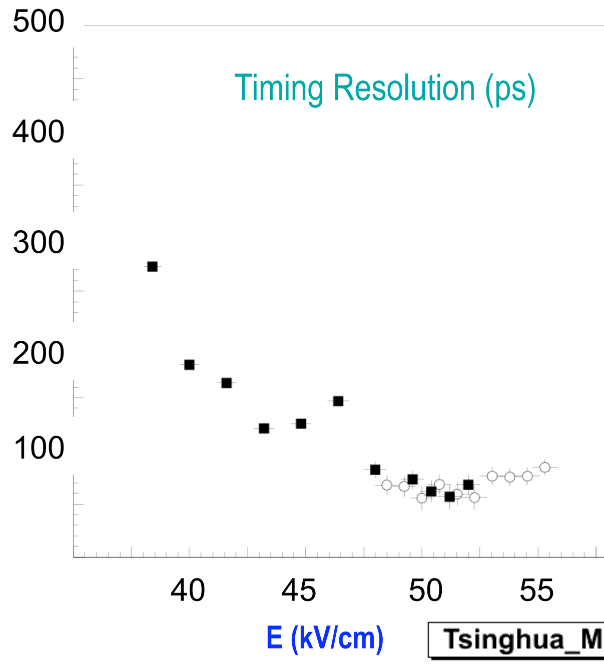
A pseudo 2π detector with scintillator covering the whole iron bars, leaving the gaps in-between uncovered. Geometric Acceptance: 56.6% at $|\eta|<0.8$

1. muon detection efficiency: ~45%, pion detection efficiency: 0.5-1% at $p_T>2$ GeV/c
2. muon-to-pion enhancement factor: 50-100 within MTD geometric acceptance
3. muon-to-hadron enhancement factor: 100-1000 including track matching, TOF and dE/dx
4. dimuon trigger enhancement factor from online trigger: 10-50

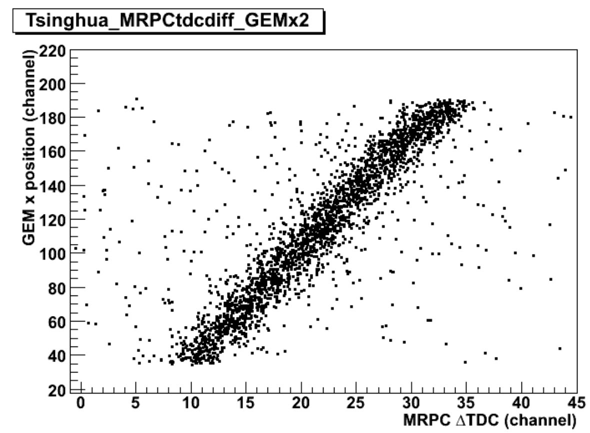
→This together with DAQ1000 will greatly enhance STAR capability for J/ψ and other dilepton studies at RHIC II and a possible future electron-ion collider

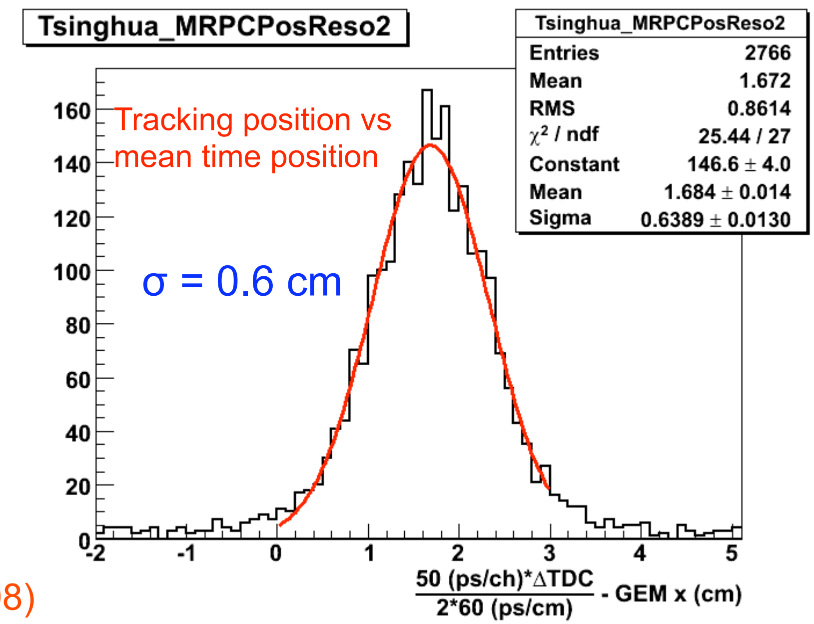
MTD: Beam Test Results





Tracking position vs mean time position





HV: ± 6.3 KV

gas mixture: 95% Freon + 5% isobutane

time resolution: ~ 60-70 ps

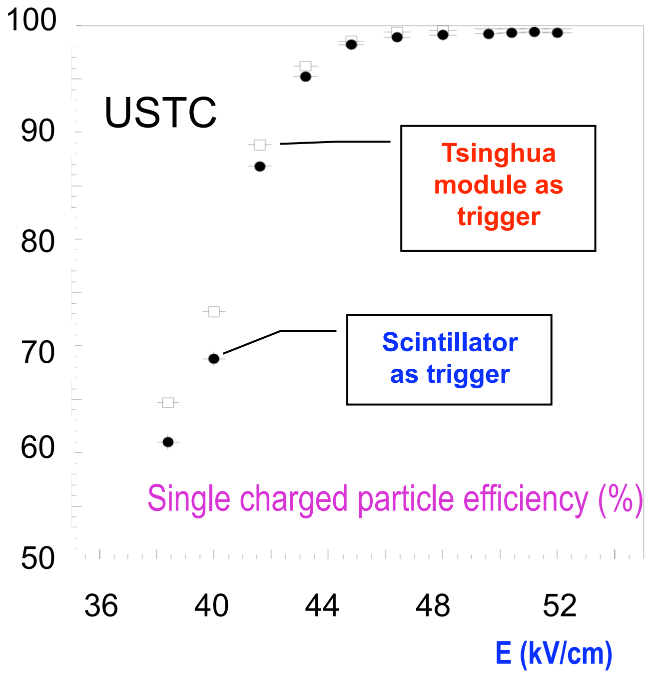
spatial resolution: ~ 0.6-1cm

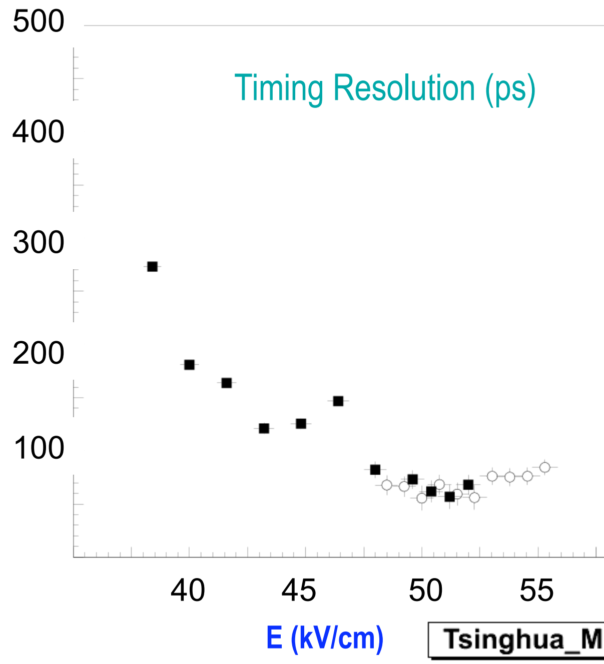
efficiency: > 95%

consistent with cosmic test results

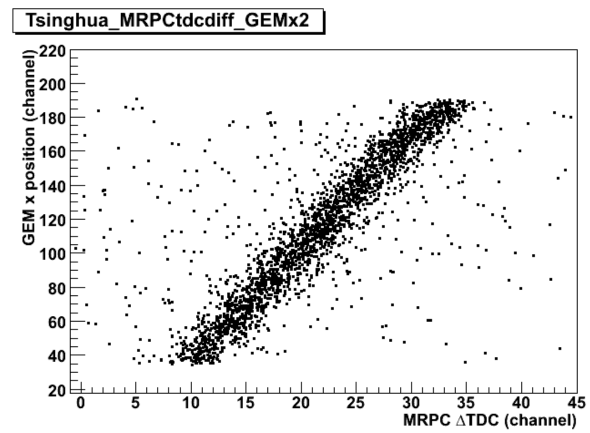
Y. Sun et al., nucl-ex/0805.2459; NIMA 593, 430 (2008)

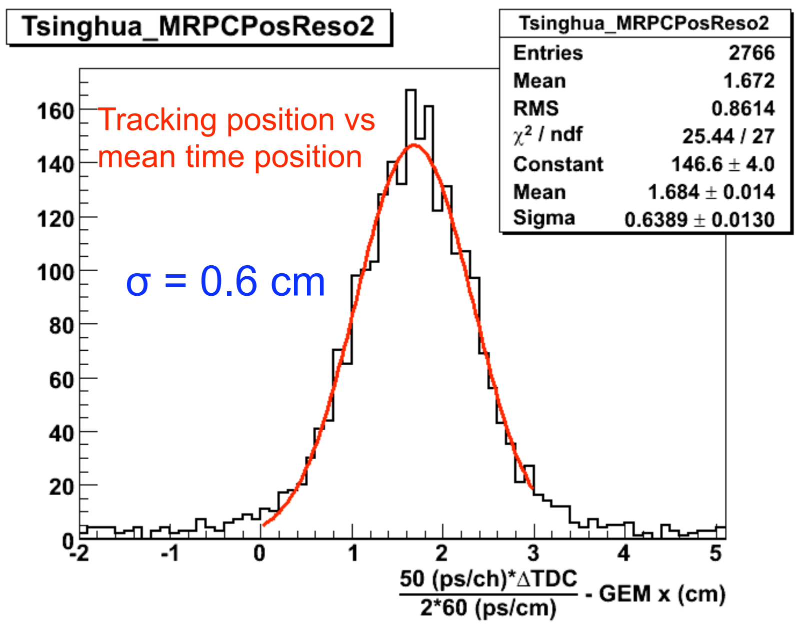
MTD: Beam Test Results





Tracking position vs mean time position





Proposal to STAR anticipated in next 1-2 months

BNL STAR Group lead role in other very important developments

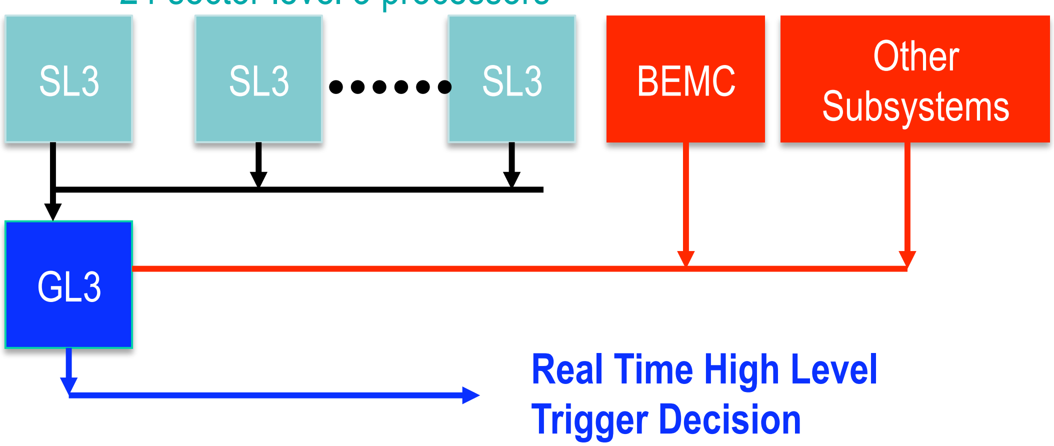
- Barrel EMC Shower-Max (BSMD) Upgrade
  - BSMD is currently the slowest detector in STAR for FY10
  - Plan is to modify the data sender and data receiver electronics boards to the DAQ1000 flavor
  - Design is in the last stages
  - Goal is about 3% dead time at 1 kHz (currently 30% dead @ 300 Hz)

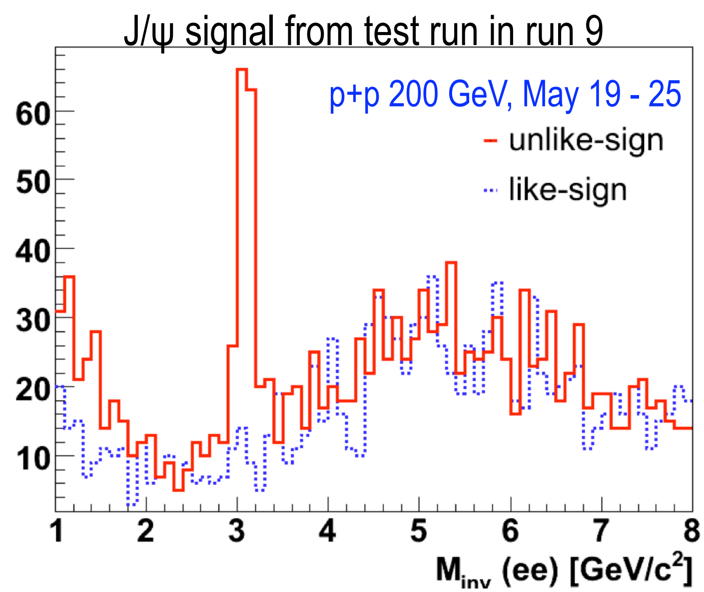
- Forward Gem Tracker (FGT) Prototype FY10
  - Will have an electronics "slice" of the FGT detector prototype in FY10
  - Full DAQ, Trigger & Slow Controls interface will be implemented -- in progress

- High level Online Trigger for Quarkonia:

Van Buren, Fisyak, Landgraf, Lauret, Ljubicic, Hao Qiu, Tang, Xu

24 sector level 3 processors





J/ψ counts seen with HLT in a few days exceeds total counts seen by STAR previously in year 2006

BNL STAR Group lead role in other very important developments

- Barrel EMC Shower-Max (BSMD) Upgrade
  - BSMD is currently the slowest detector in STAR for FY10
  - Plan is to modify the data sender and data receiver electronics boards to the DAQ1000 flavor
  - Design is in the last stages
  - Goal is about 3% dead time at 1 kHz (currently 30% dead @ 300 Hz)
- Forward Gem Tracker (FGT) Prototype FY10
  - Will have an electronics "slice" of the FGT detector prototype in FY10
  - Full DAQ, Trigger & Slow Controls interface will be implemented -- in progress
- High level Online Trigger for Quarkonia:

  Van Buren, Fisyak, Landgraf, Lauret, Ljubicic, Hao Qiu, Tang, Xu

BNL STAR Group members are aggressively engaged in technical developments to significantly extend the reach and the efficiency of the STAR scientific program, now and in the future

BNL STAR Group lead role in pushing the envelope of computing

- Development of Cloud Computing
  - Outside interest: described in Newsweek, May 7, 2009
  - Opens up a new regime for resource utilization

- Development of distributed data processing with the Grid
  - Successful transfer of Run 9 data in real time to KISTI in Korea
  - Multi-site data transfer: algorithmic coordination to find fastest path
    - Ph. D Computer Science project from Prague

- Tracking in the multicore era using cellular automata

- Broad expertise in detector calibration and understanding
  - Software design and integration: DAQ1000, …
  - BNL team heavily involved in positive outcome of TPC review

Conclusions

- The STAR BNL research Group is a highly effective, talented, productive group of aggressive researchers who are pioneering new directions in heavy ion research. The pace of progress has been breathtaking!
- The efforts of group members are having a high impact on the ongoing and future international heavy ion research effort
- Group members are pioneering new technology which has opened/ will open entirely new research directions in the field
- The members of the group who are developing their careers show outstanding promise, and are already in important positions of scientific leadership, both within STAR and in the wider community
- The group is playing a proactive role in educating the next generation of scientists in the field.